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Performance of Silicon Solar Cells under the Climatic Conditions of Bangladesh, Part III. Performance of PV Cells under Defuse Light and Applicability for Home Lighting

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Abstract

In part II of this series, it was reported that the solar home system (SHS) supplied by REB in some islands of the Meghna river in the district of Narsingdi could not meet the demand of the recipients in the rainy season when the sky remained overcast with cloud. The tilt angle for all installations was 45^o facing south. In this study, effects of direct and diffuse sunlight with variation of tilt angles from 0^o to 45^o were studied using a mono crystalline silicon cell. Pyranometer and the solar panel were kept under identical conditions. Energy absorbed by the solar panel in diffuse sunlight was found 0.55% of that received by the Pyranometer under similar conditions showing that mono crystalline silicon solar cell of the type under study was not suitable for use in SHS. Moreover, the gap between the panel and the solid surface below it has significant effects on the efficiency of the solar cell. Further similar study using different kinds of cells- mono crystalline, poly crystalline and amorphous is needed for proper designs of SHS. Optimization of the gap between the panel and the solid surface below it is important for roof-mounted and ground-mounted panels.

Key words: Silicon solar cells, Tilt angle, Diffuse light, Home lighting, Monocrystaline.

Introduction

In a recent communication from IFRD (Eusuf *et. al*. 2005), it has been shown that solar PV systems have been installed in some islands in the Meghna River in the district of Narshingdi. 795 houses including a rural clinic were provided with solar home systems (SHS) to supply electricity for running fans, lights and refrigerators. Overall efficiency of the polycrystalline cells used was found to be 9.5%. Although the designed tilt angle was 45^o, consideration of solar insolation data over the whole year has led to an optimum tilt angle between 23^o and 30^o.

Although solar energy is exhaustible and pollution free, it has two main disadvantages. Firstly, it comes in a very dilute form requiring large area for a particular need of power and secondly, the intensity of solar radiation varies depending on the time of the day, season of the year and the condition of the sky. Moreover, because of the diurnal rotation of the earth about its own axis and eccentricity of the revolution of the earth with the sun, angle with the horizontal, azimuth angle and sun-tracking become important for catching high amount of solar energy.

In Narshingdi (Eusuf *et. al.* 2005), panels in the households are fixed at a tilt angle of 45^o, the azimuth angle being zero. According a survey carried out in 2002, it was found that, in the rainy season when the sky remains overcast for number of days, PV system is not capable enough to meet the demand of the households i.e. diffuse light is not intense enough to provide designed amount of electricity (overall) to meet the demand. The autonomy period designed was 3 days.

The objectives of this report are to study the efficiency of solar cells in summer and winter seasons and also under diffused light. Sizing of the solar home systems is also discussed to select appropriate PV systems so that different insolation conditions are taken care of while designing a PV system for a particular need.

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Materials and Methods

Photovoltaic panel used was the same as described in part1(Eusuf *et. al.* 1999) of this series. The photovoltaic panel used was made of mono crystalline silicon cell supplied by NIHON SHISETSU KOGYO CO Ltd, Japan. It was mounted horizontally on the roof of IFRD building of the BCSIR. Voltage and current in different operating conditions are determined by following the same procedure as described in part1(Eusuf *et. al.* 1999) of this series.

KIPP AND ZONEN pyranometer was used to collect radiation data. The procedure followed was the same as described in another communication from IFRD (Eusuf *et. al.* 1988). The pyranometer was mounted close to the solar panel with the intention that both the solar cell and the pyranometer were exposed to the same insolation, wind and ambient temperature conditions.

Results and Discussion

Effects of seasons and tilt angles

As stated above, solar insolation at a particular location varies with the season. Moreover, if the solar rays fall perpendicularly on the panel, amount of direct rays will be higher expectedly leading to better performance of the solar cells. Efficiency of the panel, as measured using the equation,

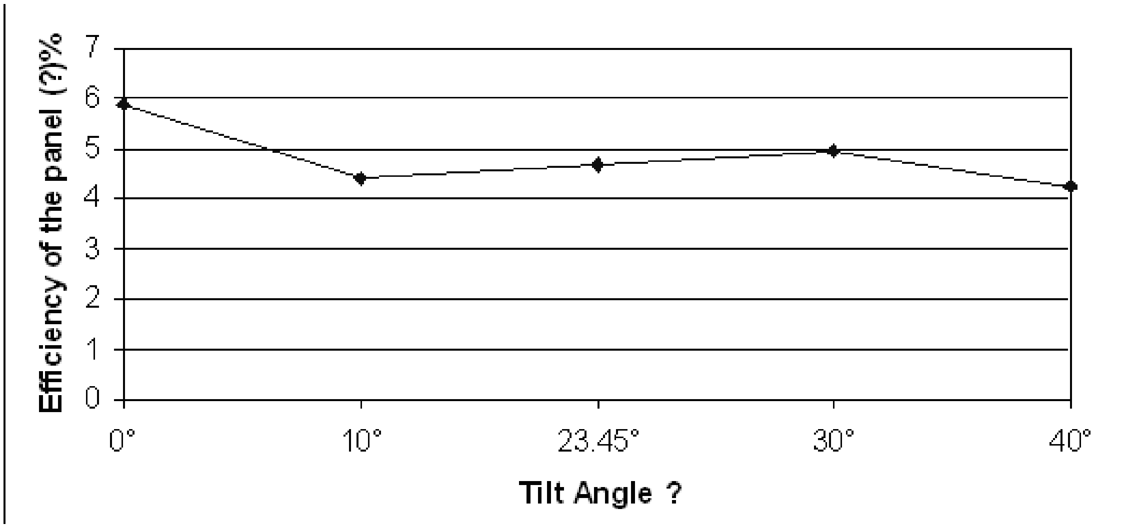
$$\eta = \frac{\text{Current X Voltage}}{\text{Insolation X Area}} \text{X} 100$$

are given in the Table I for the month of June (19-25 June, 2006) and Table II for the month of December (17-24 December 2006). The values are also plotted in Figure 1 (June, 2006) and Figure 2 (December, 2006) to show the effect of tilt angles in summer and winter respectively. The latitude of Dhaka is 23.45^o N and as such the sun, during the period of experiment in June has a zenith angle almost close to zero at noon. The efficiencies as shown in the Table I and Figure 1 are small varying from 5.89% to 4.22%. It is to be noted that pyranometer is placed horizontally and always represents horizon values. As seen from table I, total insolation received per day varied from 2.47 kWh/m^2 to 5.06 kWh/m^2. The variation was due to the occasional cloudiness during the period of the experiment. The low values in summer may be attributed, prima facie, to high ambient temperature and thus high solar cell temperature. Other factors, such as cell characteristics, may also contribute to the low efficiency. As seen from Figure 1, effect of variation of tilt angle is not very significant. In June, with the increase of tilt angle, efficiency should decrease significantly. With the increase of tilt angle, average distance from the surface increases, thus leading to lower temperature of the cell compensating for the higher tilt angle. Further study is needed to confirm this aspect. But this study clearly shows that PV panel should be fixed in such a way that an appreciable gap exists between the surface and the panel to offset the warming up effect of the solid surface below the panel. In developing countries including Bangladesh, solar panels are mostly fixed on tin sheet (tinned corrugated iron sheet) which has significant warming up effect on the panels.

Winter results are significantly different from summer results (Table II and Figure 2). During the period of experiment in December (17-24 December), the sun is at the winter solstice i.e. approximately 46^o south of Dhaka, location of the experiment. Efficiencies of the panels are consistently higher than those in summer. Moreover, as expected, the efficiency increases with the increase of tilt angles. Since the panel temperature is lower in winter than that in summer, even with tilt angles 0^o, the efficiency (6.6%) is greater than

Table I: Efficiencies of the panel for different tilt angles in summer (June 2006)

Date	Tilt Angle θ	Total energy received by the Panel (kWh/m^2)	Total energy received by the Pyranometer, (kWh/m^2)	Efficiency of the panel (η) %
19-06-2006	0°	0.192	3.259	5.89
20-06-2006	10°	0.109	2.469	4.40
26-06-2006	23.45°	0.150	3.200	4.68
21-06-2006	30°	0.250	5.060	4.95
22-06-2006	40°	0.151	3.580	4.22

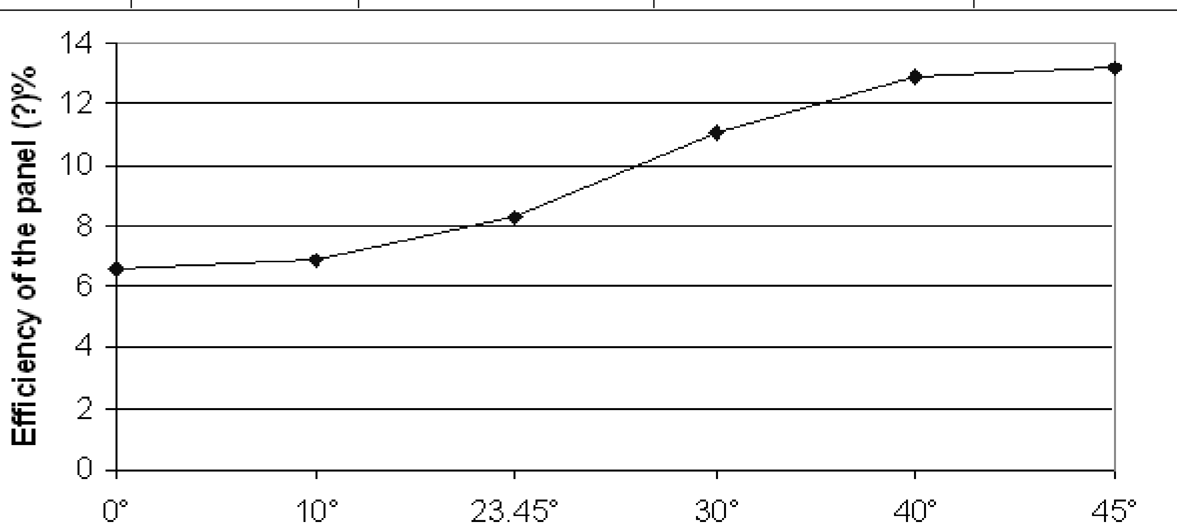


Tilt Angle θ

Fig. 1: Variation of efficiencies with tilt angles in summer (June 2006)

Table II: Efficiencies of the panel for different tilt angles in winter (December 2006)

Date	Tilt Angle θ	Total Energy Received by the Panel (kWh/m^2)	Total Energy Received by the Pyranometer, (kWh/m^2)	Efficiency of the panel (η) %
17-12-2006	0^o	0.260	3.950	6.60
18-12-2006	10^o	0.189	2.720	6.90
19-12-2006	23.45^o	0.231	2.780	8.30
20-12-2006	30^o	0.332	2.990	11.10
21-12-2006	40^o	0.439	3.410	12.87
24-12-2006	45^o	0.408	3.090	13.20



Tilt Angle θ

Fig. 2: Variation of efficiencies with tilt angles in winter (December 2006)

Table III: Operating voltage and operating current on 1st July 2008

Time	Current, I (A)	Voltage, V (v)	IV (w)	Time	Current, I (A)	Voltage, V (v)	IV (w)
9-30	0.04	0.10	0.004	14-15	0.16	0.50	0.080
9-40	0.06	0.20	0.012	14-20	0.17	0.55	0.091
9-50	0.04	0.10	0.004	14-25	0.18	0.60	0.108
9-55	0.04	0.10	0.004	14-30	0.18	0.60	0.108
10-00	0.04	0.10	0.004	14-35	0.18	0.60	0.108
10-05	0.05	0.05	0.003	14-40	0.18	0.70	0.126
10-15	0.06	0.10	0.006	14-45	0.19	0.70	0.133
10-20	0.10	0.40	0.040	14-50	0.20	0.80	0.160
10-25	0.15	0.30	0.045	14-55	0.22	1.00	0.220
10-30	0.18	0.35	0.063	15-00	0.22	1.00	0.220
10-35	0.12	0.30	0.036	15-05	0.22	1.00	0.220
10-40	0.04	0.20	0.008	15-10	0.24	1.20	0.288
10-45	0.04	0.20	0.008	15-15	0.24	1.20	0.288
10-50	0.04	0.20	0.007	15-20	0.24	1.30	0.312
10-55	0.04	0.10	0.004	15-25	0.24	1.30	0.312
11-00	0.03	0.10	0.003	15-30	0.24	1.30	0.312
11-05	0.02	0.10	0.002	15-35	0.22	1.20	0.264
11-10	0.01	0.00	0.000	15-40	0.22	1.10	0.242
11-15	0.04	0.10	0.004	15-45	0.20	0.90	0.180
11-20	0.04	0.10	0.004	15-50	0.20	0.90	0.180
11-25	0.03	0.10	0.003	15-55	0.25	1.00	0.250
11-30	0.02	0.00	0.000	16-00	0.25	1.00	0.250
11-40	0.02	0.10	0.002	16-05	0.23	1.10	0.253
11-45	0.02	0.10	0.002	16-10	0.23	1.10	0.253
11-50	0.01	0.00	0.000	16-15	0.22	1.05	0.231
12-00	0.02	0.05	0.001	16-20	0.20	0.90	0.180
12-15	0.03	0.10	0.003	16-25	0.20	0.80	0.160
12-25	0.07	0.20	0.014	16-30	0.20	0.70	0.140
12-30	0.06	0.20	0.012	16-35	0.18	0.60	0.108
12-35	0.06	0.20	0.012	16-40	0.16	0.50	0.080
12-40	0.10	0.30	0.030	16-45	0.14	0.40	0.056
12-45	0.12	0.40	0.048	16-50	0.13	0.40	0.052
12-50	0.14	0.40	0.056	16-55	0.12	0.35	0.042
12-55	0.14	0.40	0.056	17-00	0.12	0.30	0.036
13-00	0.12	0.40	0.048	17-05	0.11	0.25	0.028
13-05	0.10	0.30	0.030	17-10	0.12	0.30	0.036
13-10	0.14	0.50	0.070	17-15	0.07	0.20	0.014
13-15	0.10	0.40	0.040	17-20	0.10	0.25	0.025
13-20	0.17	0.60	0.099	17-25	0.10	0.25	0.025
13-25	0.14	0.40	0.056	17-30	0.13	0.40	0.052
13-30	0.10	0.30	0.030	17-35	0.12	0.35	0.042
13-35	0.12	0.40	0.048	17-40	0.06	0.15	0.009
13-40	0.14	0.50	0.070	17-45	0.05	0.10	0.005
13-45	0.10	0.30	0.030	17-50	0.06	0.10	0.006
13-50	0.06	0.15	0.009	17-55	0.04	0.10	0.004
13-55	0.06	0.15	0.009	18-00	0.04	0.05	0.002
14-00	0.10	0.20	0.020	18-05	0.03	0.10	0.003
14-05	0.04	0.25	0.010	18-10	0.02	0.05	0.001
14-10	0.16	0.50	0.080	18-15	0.02	0.00	0.000

the highest value (5.89%) in summer. This supports the view that high panel temperature decreases panel efficiency significantly.

Efficiency under diffused light

Experiments were performed on 1st July 2008- a rainy day, the entire sky being overcast with cloud. Under these natural conditions, current-voltage characteristics were studied with a constant load and the results are given Table III. Readings were taken from 9.30 am to 6.15 pm i.e. up to the time till the voltage found gradually decreased to zero. It is seen from the Table that voltages found were mostly below 1V. Out of 97 readings, in only 15 cases, voltages ranged from 1.0 to 1.3V, current varying from 0 mA to 240 mA. Efficiency calculated based on the pyranometer value under the same condition came out to be 0.55%.

In order to see the effect under cloud-free conditions in winter, both the pyranometer and the panel were covered with black umbrella of the same size and the results are shown in Table IVa (without shade) and in Table IVb (with shade). It is seen that, as found in cloudy conditions in July, in December also, under diffused light, the voltage was below one volt and current was less than 170 mA.

Conclusion

As increase of cell temperature decreases cell efficiency significantly, there should be appreciable gap between the surface and the panel to offset the warming up effect of the solid surface below the panel. Further work is needed to determine the acceptable gap depending on the nature of the solid surface below the panel.

As the energy utilized by the panel under study in diffused sunlight is only 0.55% of that received by the pyranometer under similar conditions, solar cell of the type (mono crystalline silicon) under study will generate much less electricity than the designed value. Work on polycrystalline and amorphous cells are needed.

Table IVa: Operating voltage and operating current on 31st December 2008 without shade (Global radiation)

Time	Tilt Angle, θ	Voltage (V)	Current (A)	IV (W)	Insolation (W/m^2)	η (%)
11-20	45^O	11.4	0.56	6.384	348.129	13.50
11-25	45^O	11.3	0.55	6.215	348.129	13.19
12-50	23.45^O	10.2	0.52	5.304	340.722	11.50
13-00	23.45^O	10.1	0.52	5.252	333.315	11.60

Table IVb: Operating voltage and operating current on 31st December 2008 with shade (Diffuse radiation only)

Time	Tilt Angle, θ	Voltage (V)	Current (A)	IV (W)	Insolation (W/m^2)	η (%)
11-35	45^O	0.4	0.14	0.06	118.512	0.37
11-40	45^O	0.4	0.15	0.06	111.105	0.39
11-45	45^O	0.4	0.15	0.06	111.105	0.39
11-50	45^O	0.4	0.15	0.06	111.105	0.39
11-55	45^O	0.4	0.15	0.06	111.105	0.39
12-20	23.45^O	0.5	0.16	0.08	111.105	0.53
12-25	23.45^O	0.5	0.16	0.08	111.105	0.53
12-30	23.45^O	0.5	0.16	0.08	111.105	0.53
12-35	23.45^O	0.5	0.17	0.09	103.698	0.60
12-40	23.45^O	0.5	0.17	0.09	103.698	0.60

It is seen from Table IVa and IVb, under diffused light, mono crystalline silicon solar cell can not produce enough power to sustain a solar home system (SHS).

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